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Procedia CIRP 48 (2016) 90 – 95

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23rd CIRP Conference on Life Cycle Engineering

Service Selection Method for Facilitating Life Cycle Options in Environmentally Benign Product and Service Business

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Abstract

Designing environmentally benign businesses requires the selection of an appropriate combination of services that can facilitate life cycle options (LCOPs), reduce the environmental load, and satisfy user needs. This study proposes a method of identifying services for facilitating the effectiveness of LCOPs and combining them with those identified based on user needs. The effectiveness of the proposed method is demonstrated by applying it to a managed document service.

Peer-review under responsibility of the scientific committee of the 23rd CIRP Conference on Life Cycle Engineering

Keywords: productct and service system; life cycle options; user need; life cycle simulation

1. Introduction

Given the increasing environmental concerns, manufacturing industries must turn their businesses into environmentally benign operations that minimizes environmental impacts and resource consumption. However, manufacturing companies find it difficult to employ life cycle options (LCOPs), a means of reducing the environmental load and resource consumption during product life cycles, when simply selling their products to customers [1]. This is why environmentally benign businesses based on the Product Service System (PSS) have recently gained research attention. This study defines an environmentally benign PSS business (or "e-PSS business") as any business that provides products and services designed to reduce the environmental load and resource consumption through life cycle options and delivery modes (delivery modes are ways of providing products and services to customers).

Providing services for securing the execution of LCOPs is useful for effective LCOPs implementation. Companies must also maintain controllability over their products, not only in the beginning of the life cycle (BoL) but also in the middle (MoL) and the end (EoL), by changing the delivery mode—for example, from selling to leasing.

In designing e-PSS businesses for products, we therefore need to select the proper combination of life cycle options, services, and delivery modes. A number of studies have been conducted on PSS design methods [2], most focusing on the user [3, 4]. Schmidt et al. propose a design method consisting of three layers: the customer, customer barriers, and solutions. They demonstrate a mechanism by which a PSS can increase customer acceptance by reducing the influences of customer barriers. Since environmental friendliness is regarded as inherent to a PSS, design methods for reducing the environmental load have also emerged.

Thus, current design methods consider either user needs or the environmental load; however, services for satisfying user needs are not necessarily the same as those for facilitating the effectiveness of LCOPs. If the provider (the company providing products and services to users, which can be, but is not necessarily, the manufacturer) selects services based only on user needs, they may have little effect on proper LCOPs execution. Thus, services should be selected based on both user needs and their effects on LCOPs.

Peer-review under responsibility of the scientific committee of the 23rd CIRP Conference on Life Cycle Engineering
doi:10.1016/j.procir.2016.04.082

This study proposes a design procedure for the e-PSS business that considers the relations among user needs, services, LCOPs, and delivery modes. We focus on service method selection based on both LCOPs and user needs.

The rest of this paper is organized as follows. Section 2 outlines our e-PSS business design procedure, consisting of five steps. In Section 3, the proposed method is applied to the MDS (Managed Document Service) to demonstrate its effectiveness. Finally, Section 4 concludes the paper.

2. Service selection method for facilitating life cycle options

2.1. Outline of the service selection method

This section discusses the procedure for designing an e-PSS business for a given product, focusing on a service selection method that considers LCOPs and user needs. Figure 1 shows the outline of the proposed service selection method; it consists of five steps.

In the first step, we identify the service options based on the user actions required for the user's enjoyment of the product functions. In the second step, we identify the services that would facilitate LCOPs effectiveness based on the product characteristics. In the third step, we select the services that would satisfy the needs of each individual user. In the fourth step, we generate candidates for service combinations, considering both LCOPs and user needs. In the fifth step, candidates for e-PSS businesses are generated by specifying the proper delivery modes for the provision of each service combination. The best e-PSS business is then selected based on the Total Performance Indicator (TPI) proposed by Kondoh [5] through a life cycle simulation (LCS).

2.2. Step 1: Identification of service options

We are discussing the selection of services for a given product that provides predetermined functions; thus, we do not consider services for providing additional functions but consider only those for removing barriers to the user's enjoyment of the product functions. Such services are divided into two categories: action services and information services. The former dispatches personnel to execute actions on the user's behalf, such as operations and maintenance. The latter provides advice to users about the proper execution of the actions. These services can be identified by analyzing the user actions required to enjoy the product functions without the help of any service.

To identify service options, we first enumerate such actions, as shown in Table 1; the actions necessary for using the product are categorized in terms of the procedure for using the product. Then, we identify two types of service option, action services and information services, in relation to each user action.

2.3. Step 2: Selection of services based on effectiveness of life cycle options

In the second step, we select services for facilitating the effectiveness of LCOPs. Table 2 shows the LCOPs adopted in the MoL and EoL phases considered in this study. We do not consider LCOPs in the BoL phase, such as miniaturization, because they are not directly related to services.

First, we perform a life cycle assessment (LCA) to identify which life cycle phases have dominant environmental loads. Then, we select the LCOPs that will be effective in reducing the environmental loads in the life cycle phases with large ones.

We identify the services for facilitating the execution of the selected LCOPs by examining which user actions are related to the execution of each LCOP. In the right-most column of Table 1, we show the LCOPs related to the actions

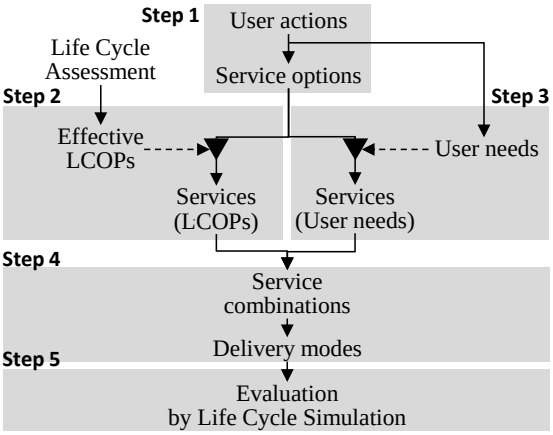

Figure 1. Outline of the method of selecting services

Table 1. The user actions

Category	Actions for using products	Related LCOPs
Prepa-ration	Selecting installation location	Increasing operation rates
	Setting up machine	
	Reading manual	
	Ordering consumables	Inventory optimization
	Setting or replacement of consumables	
	Setting machine parameters	Proper use of consumable
Opera-tion	Going to machine	
	Selection of operation modes	Proper use of consumable
		Proper use of energy
	Starting machine	
	Retract processed material	
Mainte-nance	Cleaning up of machine	Maintenance
	Application of preventive maintenance	
	repairing machine	
End of life treatment	Product return	Optimization of transportation
		Product reuse
		Parts reuse
		Recycling

needed to use the products. For example, the maintenance LCOP requires the users to carry out preventive maintenance such as parts replacement. In this case, the maintenance action service ensures a more secure maintenance execution than would be the case if it were left to the user's discretion. Moreover, the information service that gives users advice about maintenance is effective, but not as effective as the action service.

We evaluate the effect of each service on LCOPs using the LCOP execution rate evaluation proposed by Matsumoto [6]. For example, a 50% execution rate for preventive maintenance means that preventive maintenance is executed once for each two maintenance events.

We specify the increase in the LCOP execution rate by providing services based on the service category. As mentioned, the action services are more effective than are the information services in increasing the execution rate.

2.4. Step 3: Select services for satisfying user needs

In Step 3, we select services for satisfying user needs. We consider that user needs arise from the necessity of alleviating the burdens of money, effort, and time involved in enjoying product functions. For example, users feel the monetary burden of paying for electricity, the burden of the effort needed to replace consumables, and the temporal burden of consulting the manual. Although users want to reduce or eliminate these burdens, they place different emphases on each one. Measuring the weight of each burden would be difficult because there are many burdens, corresponding to the many user actions and aspects (i.e., money, effort, and time). Therefore, we examine the user weights placed on actions and aspects separately. Table 3 shows an example of burdens corresponding to each action and aspect. The weight for the p-th action is denoted by w_p and that of the q-th aspect by w_q; thus, the weight of the burden related to p-th action from the q-th aspect is calculated by $w_p \cdot w_q$.

To select services based on user needs, we quantify the effect of the service in relieving the burden via the mitigation rate r_{ij}, which represents the percentage of the i-th burden that can be relieved by the j-th service. Then, we select the services corresponding to the burdens with non-zero weights.

2.5. Step 4: Form service combinations and select delivery modes

After selecting services for facilitating LCOPs and satisfying user needs, we generate service combinations. Since we consider that the services for facilitating LCOPs selected in Step 2 are indispensable for e-PSS businesses, we combine some of the services for satisfying user needs selected in Step 3 with the services selected in Step 2. Then, we calculate the mitigation value, C_k, which denotes how much of the burden the k-th service combination can reduce, by Equation 1.

$$C_k = \sum_{j \in k} \left(\frac{\sum_i (r_{ij} \times w_{ri})}{\sum_i w_{ri}} \right) \quad (1)$$

The service combinations whose mitigation values are greater than the given level are selected for the evaluation in Step 5.

Before proceeding to Step 5, we select delivery modes for them. Delivery modes represent how to provide products and services to users. Table 4 lists the items characterizing the delivery modes proposed by Matsumoto; the delivery modes are characterized by the combinations of those items. Some items are automatically decided by selecting services and LCOPs, while others have to be specified for each combination of services. Consequently, we identify the candidates for the e-PSS businesses, which are evaluated in Step 5.

Table 2. Life cycle options considered in this study

Life Cycle	LCOPs	Intended reduction
Middle of Life Cycle	Proper use of consumable	Consumable
	Inventory optimization	Inventory
	Proper use of energy	Energy
	Batch processing	Time in operation
	Increase operation rates	Products in operation
	Maintenance	Waste matter
End of Life Cycle	Optimization of transportation	vehicle emission
	Product reuse	Virgin material
	Parts reuse	
	Recycling	

Table 3. The example of user burdens

		1	2	3
		money	effort	time
1	Setting up machine			to set up machine
2	Reading manual			to know how to use
13	corrective maintenance	cost	corrective maintenance	
14	Product return	collection cost		

Table 4. Items for defining the delivery modes

Items of delivery mode	Product delivery mode						
	Manage			Operation			
	Owner	Contract period	Charging	Operator	Installation location	Usage mode	Customer
Possible values	Customer	Unlimited	Bullet payment	Specific customer	Customer	Exclusive use	Specific customer
	Provider	Specific	Specific payment	Specific group of customer	Provider	Time sharing	Specific group of customer
			Installment payment	Non-specific customers	Third-party	Pooling	Non-specific customers
			Pey per	Provider			

2.6. Step 5: Evaluation by life cycle simulation

Among the e-PSS business candidates, we select the one that maximizes the total performance indicator (TPI), defined by Equation 2, where PC and EL denote the provider's cost and the environmental load of each e-PSS business [5]. Here, UV expresses user value, indicating how many burdens are reduced by the service combination. Moreover, TPI is evaluated by the life cycle simulation (LCS), developed based on the system proposed by Komoto [7]. The LCS is executed by generating the events that occur during the product life cycle and evaluating the results. The events comprise "product use," "maintenance," "failure," and "end-of-use," in which such events as "collection," "reuse," "recycling," "illegal dumping," and "new product installation" can occur.

$$TPI = \frac{UV}{\sum \sqrt{(PC \times EL)}} \quad (2)$$

$$UV = \sum (r_{ij} \times w_i) \quad (3)$$

3. Application to MDS

3.1. Case study setting

We applied the proposed method to MDS. We assume that the provider has a blanket contract with a company to execute an e-PSS business. We also assume that the company has 30 offices with one copier each. There are 300 employees, but every employee in the same office has the same needs. As mentioned, we assume that one type of product is provided to the user with a combination of the selected services and delivery modes that satisfies the individual user needs and

Table 5. Product feature, LCC and LCA data *1 based on [8]; *2 based on [9]; *3 based on [10]

Product feature	Value
Copy speed (/sheet)($\times 10^{-3}$)*2	0.83
Electricity consumed in operation (KW) *2	1.50
Electricity consumed in waiting (KW) *2	0.11
Electricity consumed in mode of electric power saving (KW) *2	0.08
Cost	Rate
Retail price (/product)*1	1
Manufacture cost (/product) *1	0.16
Payment of print sheet in specific payment (/sheet) *2	0.64×10^{-5}
Payment of print sheet in bullet payment (/sheet) *2	0.19×10^{-5}
Electricity rate (work)(/hour) *1	0.022
Electricity rate (wait)(/hour) *1	0.0016
Recycle cost (/product) *1	0.05
Action service for usage (/sheet) *2	0.21×10^{-4}
Action service for collection (/frequency) *2	0.0091
Action service for maintenance(/frequency) *2	0.18
Information service for usage (/month × product) *2	0.0091
Exchanging expendables (/frequency) *2	0.068
CO_2 coefficients (kg-CO_2)	
Manufacture (/product) *3	435.33
Product delivery (/product) *3	27.96
Electricity (/KWh) *3	0.41
EOL (/product) *3	0.96

Table 6. The relationship between user burdens and services

User burden \ Services		Action service					Information service									
		Replacement operator service	Computerization of paper	Delivery paper on demand	Delivery toner on demand	Carrying printed	Optimization of number	Usage instructions	Propulsive printing all at once	Suggestion kinds of paper to buy	Propulsive printing in two-colors	Suggestion kinds of toner to buy	Making manual	Propulsive printing on both sides	Visualization of usage condition	Suggesting an improvement
Money	Electric cost						+	+	+		+					+
	Cost of paper		++					+	+					+	+	+
	Cost of toner		++					+			+				+	+
Effort	Moving to copier	++														
	Carrying on prited	++				++										
	Exchanging paper			++												
	Exchanging toner				++											
Time	Tiime to know how to use	++						+					+			
	Time to move to copier	++														
	Time to select printing mode	++						+					+			
	Time to exchange paper	++				++										
	Time to select paper to buy			++						+						
	Time to select toner to buy				++							+				

facilitates LCOPs effectiveness. The features of the product are shown in Table 5. The parameters used in the LCS are set based on these features. We also refer to data in [9] and to company websites [10, 11] to estimate life cycle costs (LCC) and execute LCA during the LCS.

3.2. Identification of the service options

First, we identify the service options based on the user actions needed to enjoy the product functions of copiers. We identify 14 user actions (see Table 1). We also identify 37 potential services for those actions, including action services and information services. They are compatible with the actual services offered by the existing MDS.

3.3. Selecting services based on effectiveness of life cycle options

Figure 2 shows the relative proportions of CO_2 emissions for copiers at each life cycle phase [10]. The figure shows that the environmental load for the manufacturing and usage phases are dominant. Thus, effective LCOPs could include "using reused parts" and "using recycled material" in the manufacturing phase and "proper use of consumables," "inventory optimization of consumables," "proper use of energy," "increase operation rates," and "maintenance" in the usage phase. Since the copiers do not have the features needed to consolidate small batches into single ones, the "batch processing" LCOP cannot be adopted.

Then, we select services based on the selected LCOPs. In this case, 16 services are identified as being effective for LCOPs. We selected the four of these services that can generate a greater than 80% reduction in environmental load: replacement of operator, electronic filing, visualization of usage conditions, and advice for proper use.

3.4. Selecting services based on user needs and generating combinations of services and delivery modes

After selecting services based on LCOPs effectiveness, we select services for satisfying user needs and generate service combinations. For this purpose, we examine the mitigation rate, r_{ij}, of user burdens by means of services. Table 6 shows some of r_{ij}. The symbols "++" and "+" in the table cells indicate that the services shown in the column could reduce the burden indicated in the row by 100% and 70% respectively. The services featuring the symbols "++" or "+" in the corresponding columns are selected as candidates. The candidates for service combinations are then generated by combining the selected services based on user needs with those selected based on the LCOPs.

We select delivery modes for the generated service combinations by specifying the e-PSS businesses. Since some of the delivery mode items indicated in Table 5 (i.e., operator, usage mode, and customer) are automatically selected when selecting services and LCOPs, we need to select the owner, contract period, and installation location for each service combination.

3.5. Evaluation of the number of e-PSS businesses in the LCS

We conduct the LCS for each e-PSS business candidate for a period of 10 years with a simulation cycle of one week. We assume that the number of copies or prints is 880 per employee for a period of one week [11]. The execution rates of LCOPs are set at 0.15, 0.325, and 1.0 without any service, with the information service, and with the action service respectively.

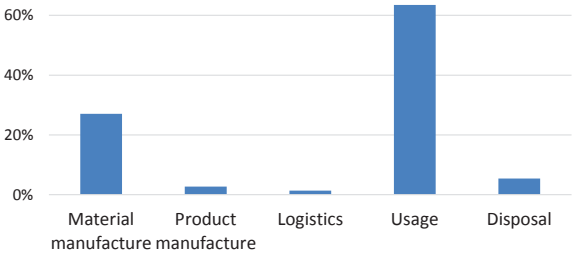

Figure 2. CO_2 emissions in each lice cycle phase [10]

Table 7. The service combination ranked in the top seven

No	Action service				Information service		
	Periodic inspec-tion	Mainte-nance	Expend-able parts	Product return	Optimization of the num-ber of ma-chine	Sup-port desk	Custom-ization of manual
A	○	○			○		
B		○	○				
C	○	○					
D	○						
E	○					○	
F				○			○
G			○	○			

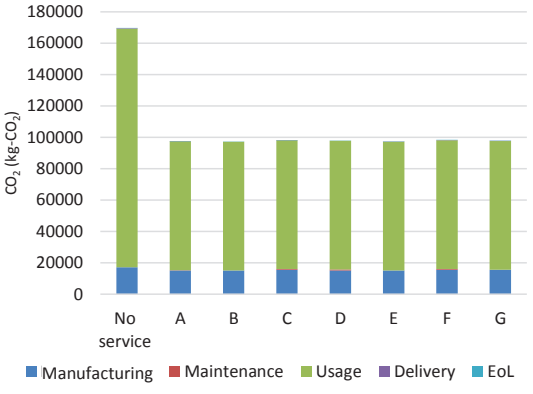

Figure 3. The LCA-CO_s result

3.6. Discussion

Table 7 shows the service combinations of the seven e-PSS businesses ranking in the top seven in terms of TPI value. Regarding increased LCOPs effectiveness by employing services based on Step 2, Figure 3 provides a breakdown of the LCA-CO_2 results by life cycle phase for the seven e-PSS businesses in addition to the business of selling products without services.

The figure indicates that the e-PSS businesses significantly reduce their environmental load in the usage phase relative to the business without services because of the services related to LCOPs in the usage phase. Moreover, a reduction of the environmental load in the manufacturing phase also occurs thanks to the maintenance service, which helps extend the lifespan of the machines and consequently reduces the number of machines needed to satisfy user needs.

4. Summary

Increasing environmental concerns are forcing manufacturing industries to turn their businesses into environmentally benign operations that minimize environmental impacts and resource consumption. We propose a design procedure for e-PSS businesses for a given product focusing on service selection. As the services needed to satisfy user needs and those needed to reduce environmental loads differ, we propose a service selection method that considers both requirements. The proposed method is applied to MDS to demonstrate its effectiveness.

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